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An Evaluation of CO_2 Sequestration in Organic-rich Shales Using COMSOL

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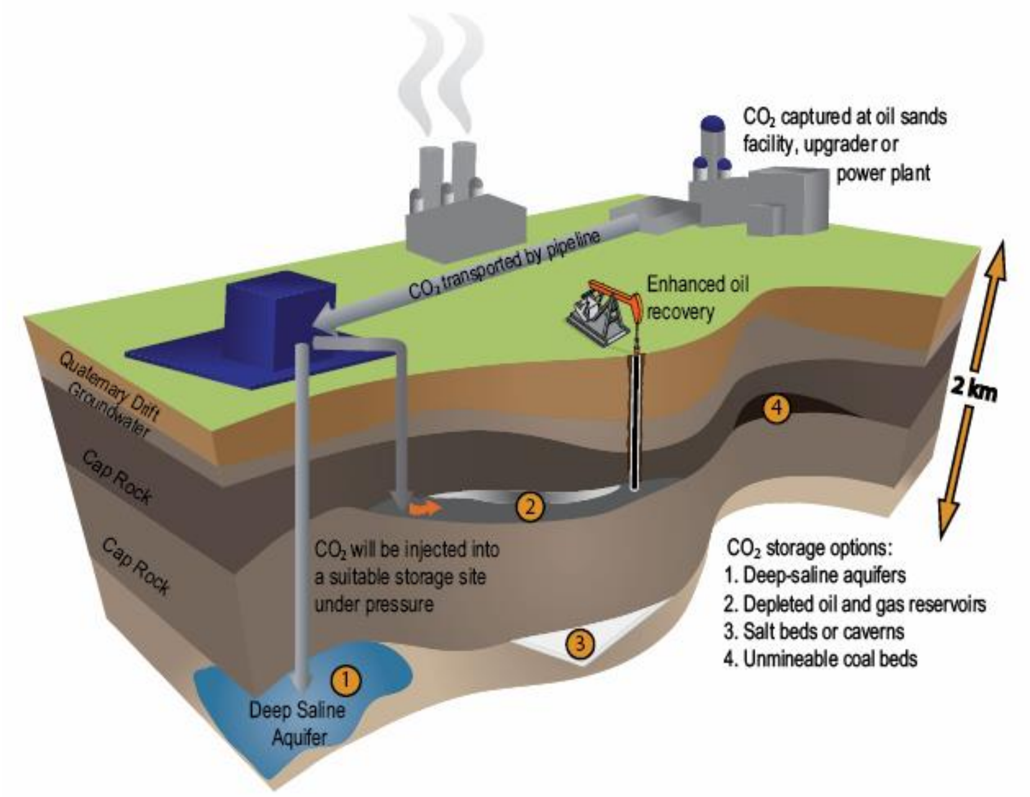
Presentation Outline

- Introduction
- Objective
- Method
- Results
- Discussion
- Summary

Carbon dioxide (CO_2) sequestration



CO_2 captured at oil sands facility, upgrader or power plant

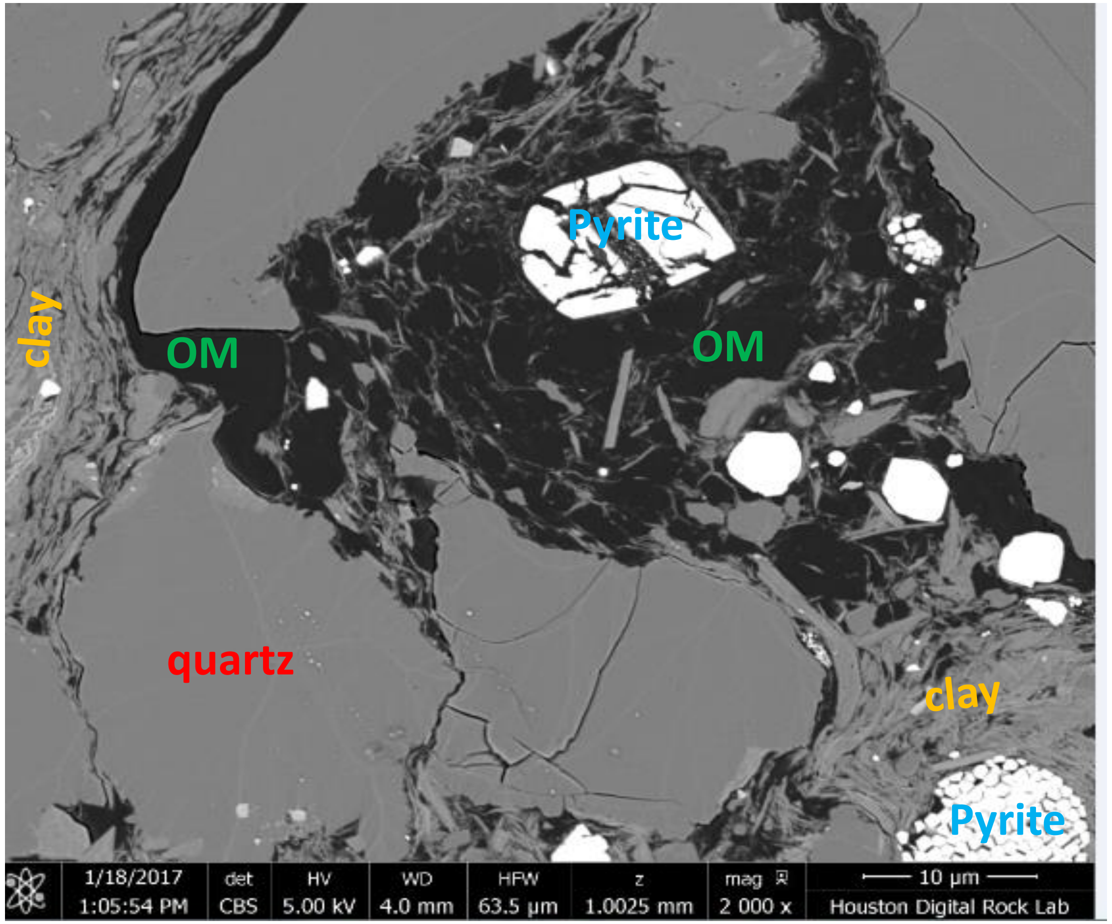
CO_2 will be injected into a suitable storage site under pressure

CO_2 storage options:
1. Deep-saline aquifers
2. Depleted oil and gas reservoirs
3. Salt beds or caverns
4. Unmineable coal beds

http://www.canada.com/technology/Players+bail+showcase+carbon+capture+project+Alberta/6526185/story.html

- Involves separation and capture of CO_2 prior to atmospheric release
- Geologic storage include:
  - organic-rich shales
- Benefits of CO_2 sequestration:
  - Mitigate GHG emissions
  - Increased oil/gas recovery

Organic-rich shales



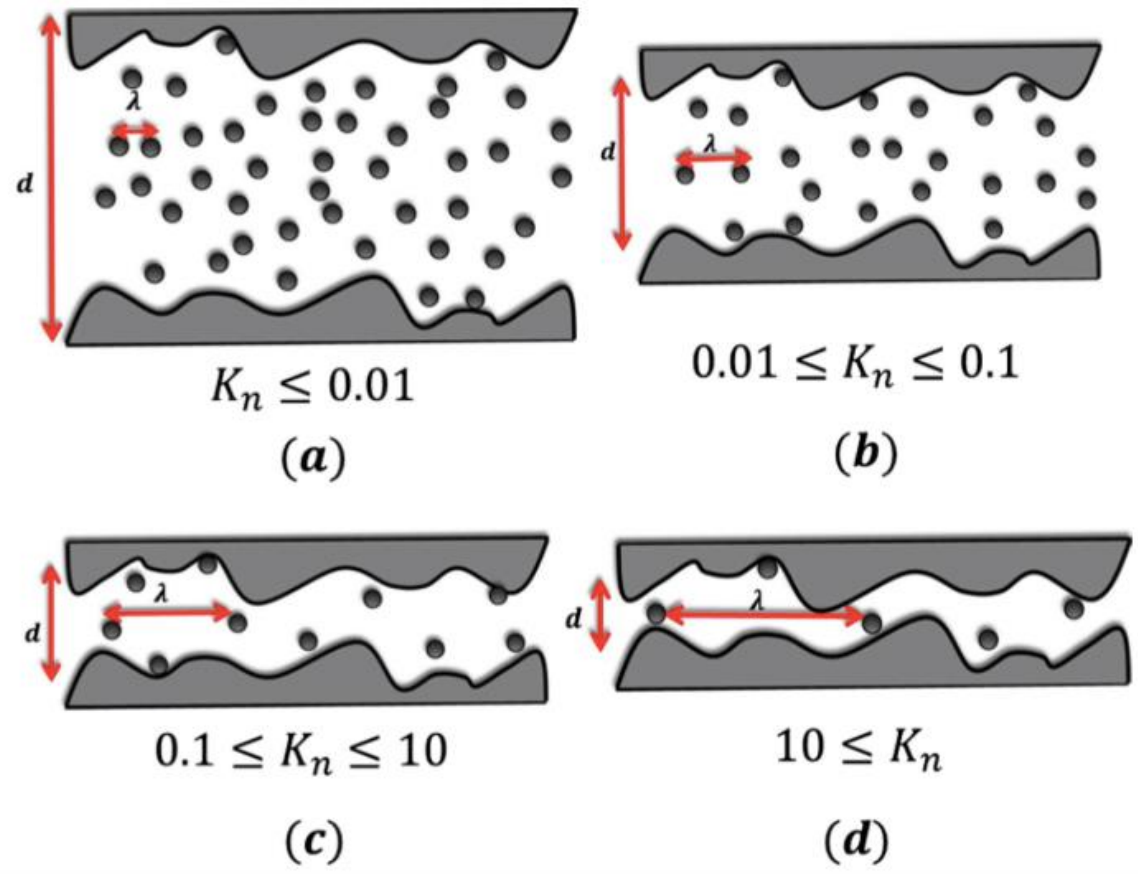
BSE image of a Chattanooga shale sample

- Consist of organic matter (OM) and mineral matrix
- Organic matter (OM) produces hydrocarbons (oil & gas)
- Degenerated organic matter leaves behind nano-pores
- OM preferentially adsorbs CO_2 over methane (CH_4)
- Ultra-tight nature minimizes leakage

Objective

- To understand the underlying mechanism(s) of CO_2 sequestration in organic-rich shales at varying pressure and temperature using COMSOL

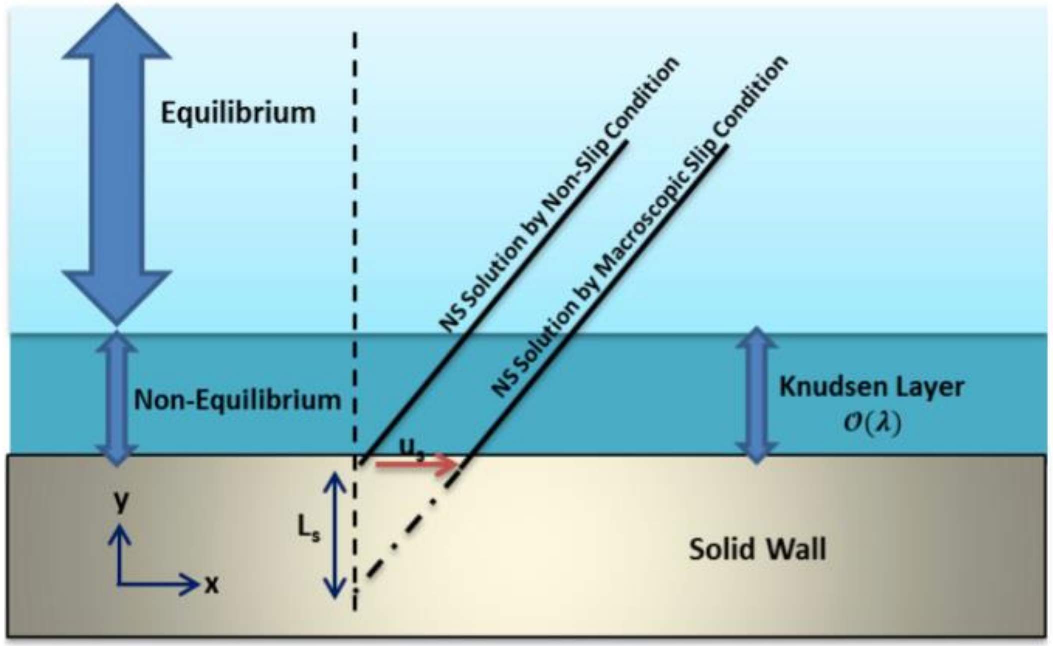
Flow regimes



(a)Continuum flow
(b)Slip flow
(c)Transition flow
(d)Free molecular flow

Schematic diagram of flow regimes
(Moghaddam & Jamiolahmady, 2016)

Knudsen layer



Schematic diagram of Knudsen layer
(Moghaddam & Jamiolahmady, 2016)

- Non-equilibrium region, where wall collision is considered
- Covers less than 20% of characteristic length in slip flow
- Slip effects are more pronounced as Knudsen number increases

Slip flow module - COMSOL

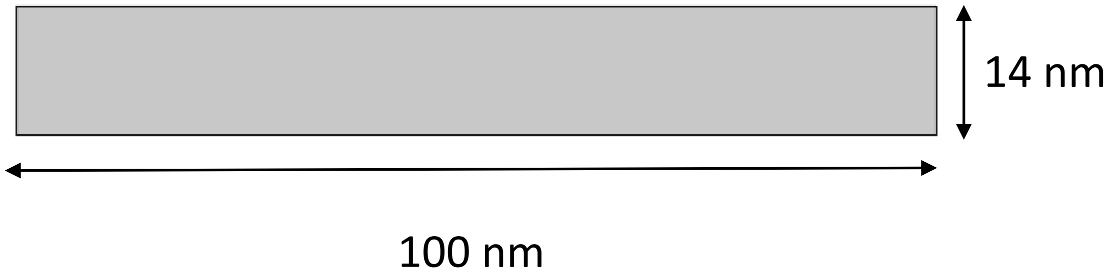
- Navier-Stokes applies but slip boundary condition is required.
- Maxwell first order slip boundary condition

- $U_{slip} = \frac{2-\sigma_v}{\sigma_v} \lambda \frac{\partial U}{\partial y}$
- $U_{slip} = U_{fluid} - U_{wall}$

where, σ_v = tangential momentum accommodation coefficient

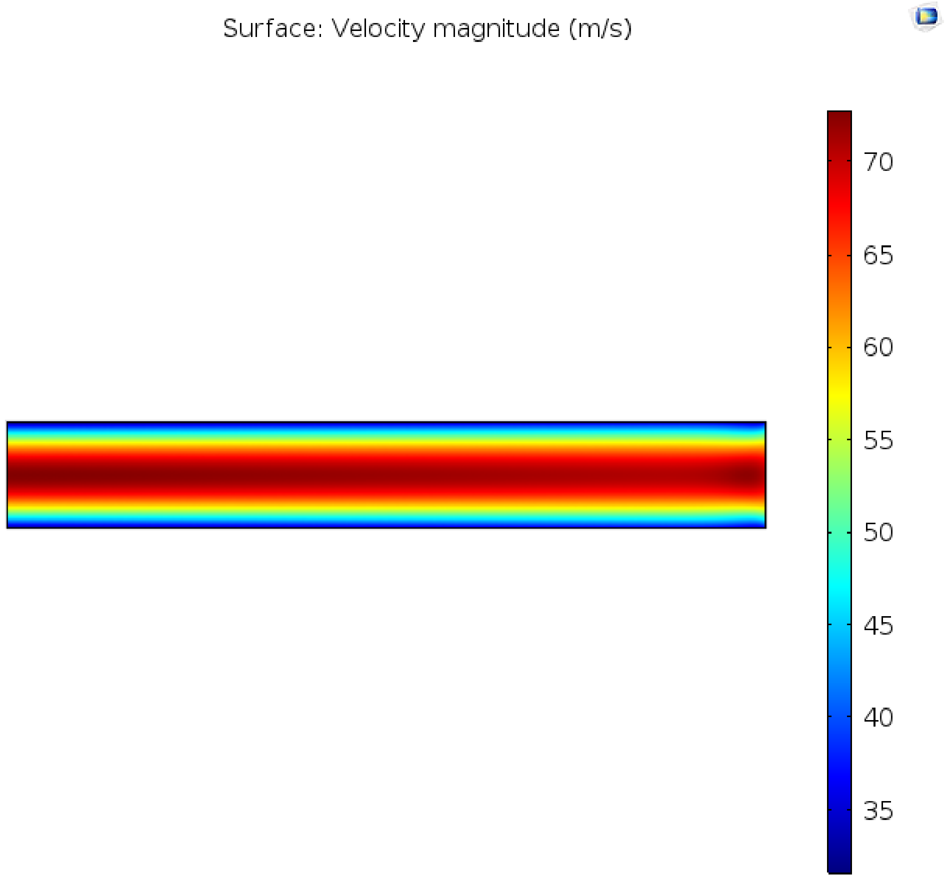
Simulation

- Fluid domain within the pore-slit driven by pressure gradient
- Fluid domain : CO_2 and CH_4 gases
- Pressures vary from 250psi to 500psi
- Temperature vary from 298K to 320K
- TMAC varied from 0.9 to 0.7

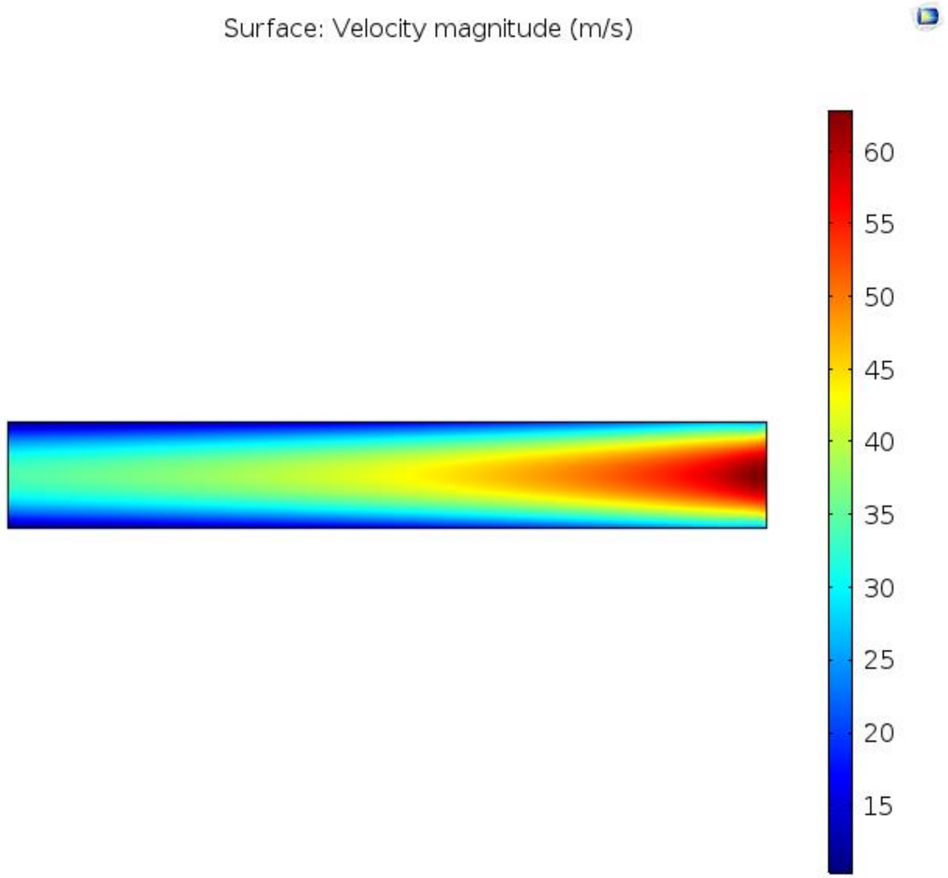


Model geometry

Results



Velocity magnitude of CH_4 at 250 psi, 298.15 K, and TMAC =0.9



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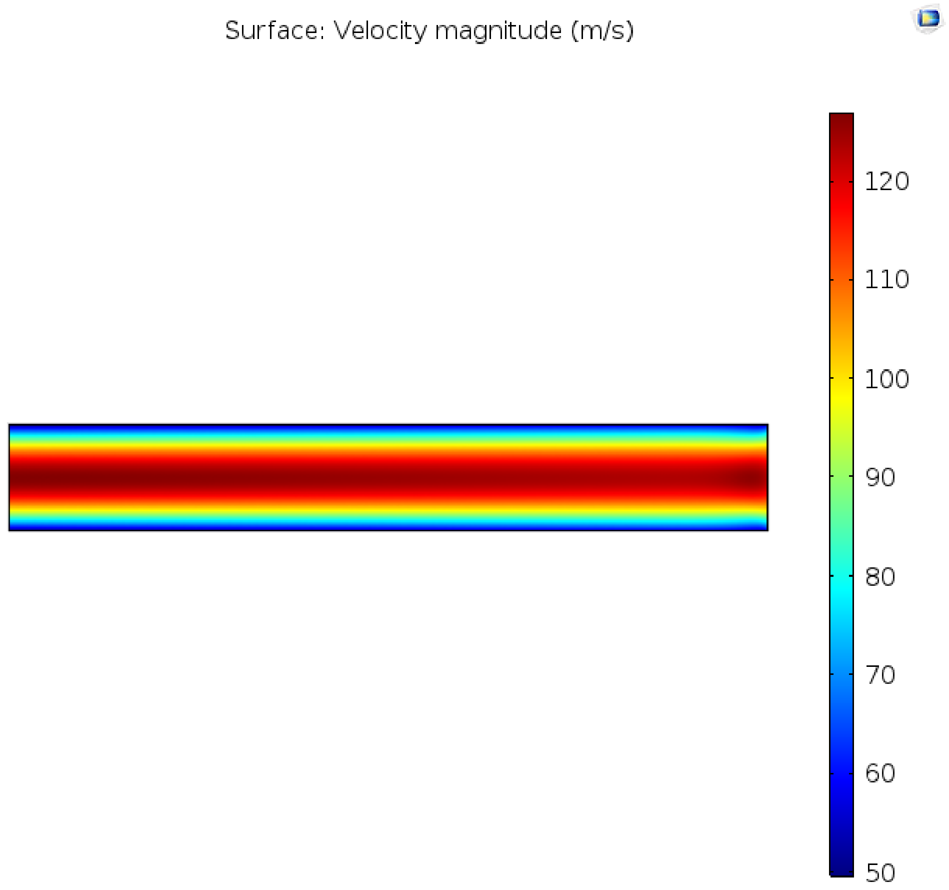
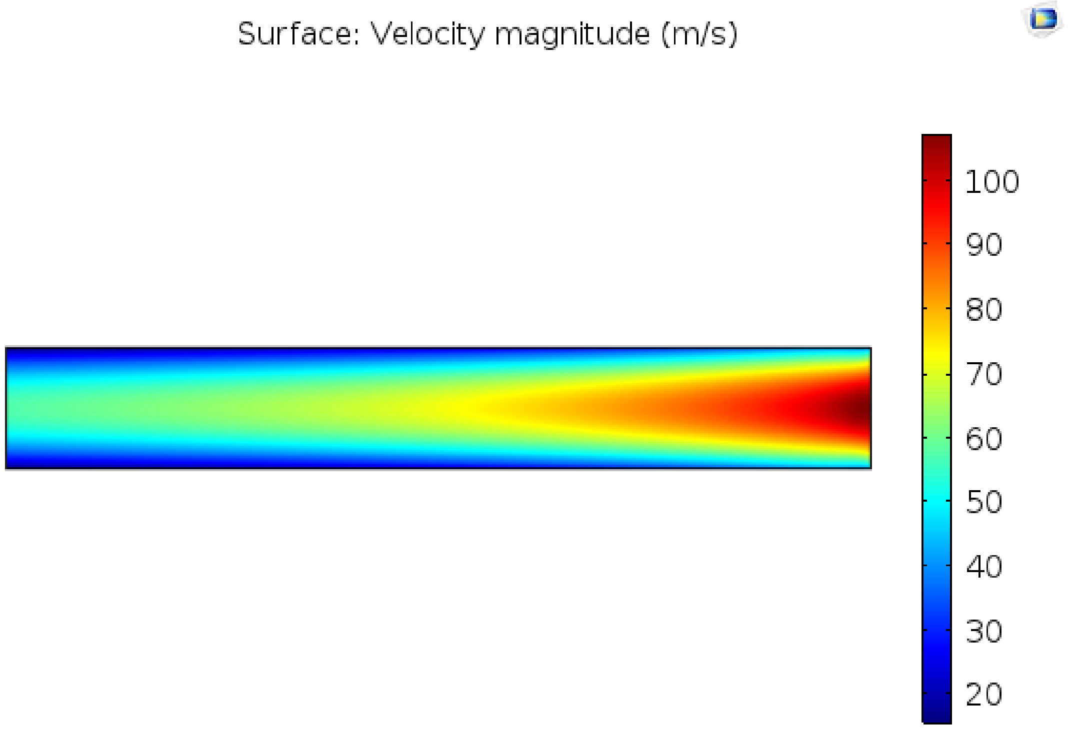
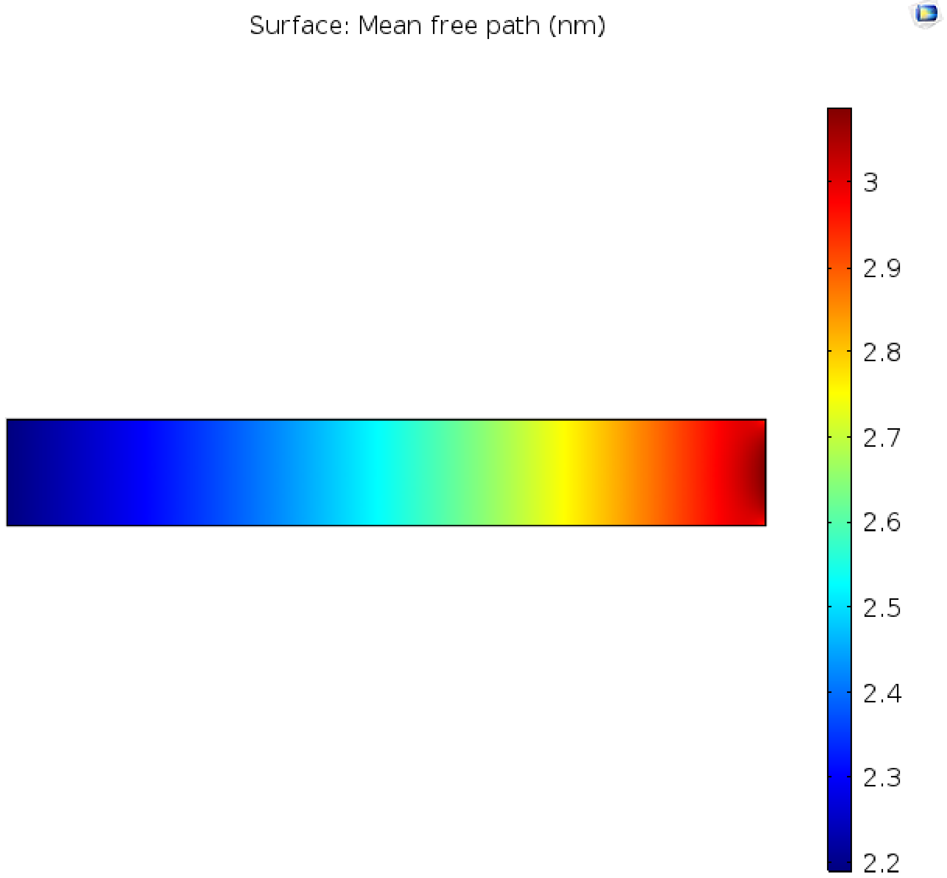


Velocity magnitude of CH_4 at 500 psi, 320 K and TMAC = 0.7

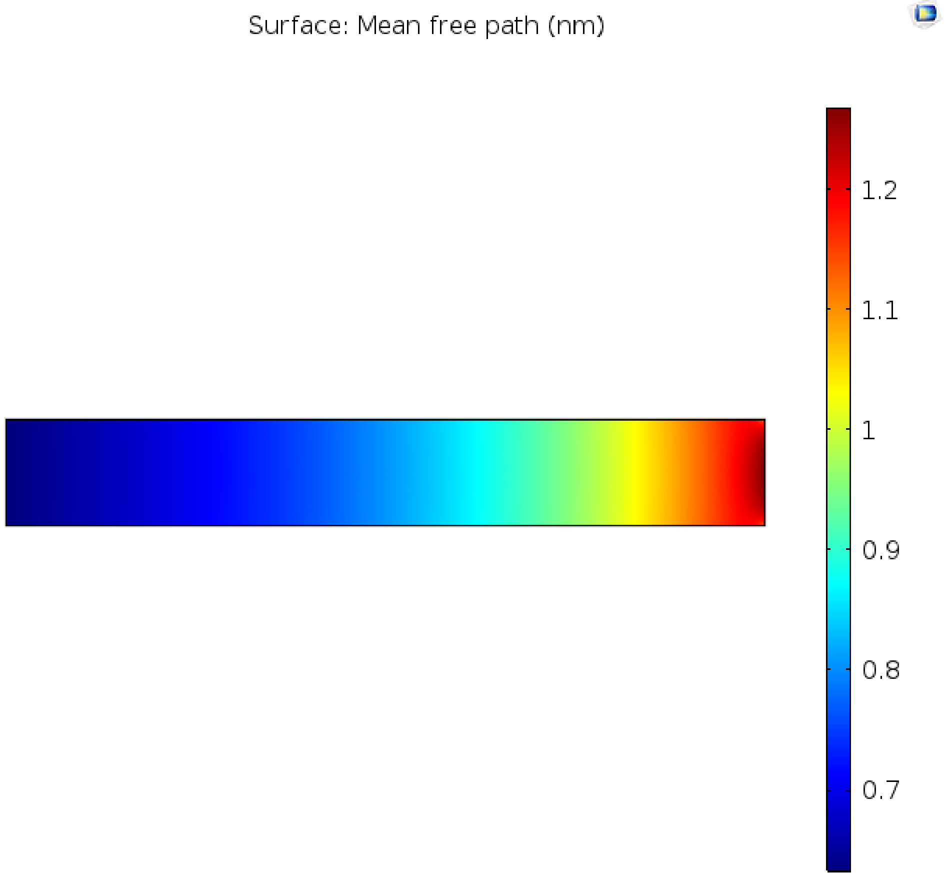


Velocity magnitude of CO_2 at 500 psi, 320 K and TMAC = 0.7

Results



Mean free path of CH_4 at P=500 psi, T=298.15K, and TMAC=0.9



Mean free path of CO_2 at P=500 psi, T=298.15K, and TMAC=0.9

Discussion

- At the same prevailing conditions, CH_4 recorded higher slip velocity and mean free path than CO_2
- Decrease in TMAC from 0.9 to 0.7 slightly caused an increase in slip velocity and mean free path in both cases
- Increase in temperature from 298.15 K to 320 K also saw an increase in the slip velocity and mean free path in both cases
- Increase in pressure from 250 psi to 500 psi resulted in a decrease in the mean free path
- Knudsen number ranged from 0.06 to 0.1

Summary

- Carbon dioxide (CO_2) is more susceptible to adsorption than methane (CH_4) in the same pore geometry and under similar conditions.
- TMAC plays an important role in gas slip models
- Slip velocity is due to pore wall interactions and therefore depends on the type of reflection gas molecules experience at the walls

Acknowledgements

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KU

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KICC

Kansas Interdisciplinary Carbonates Consortium

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THANK YOU FOR YOUR ATTENTION.

QUESTIONS ??